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Project MAC
Progress Report II
July 1964 to
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Research on the Compatible Time-Sharing System - Fernando J. Corbató

The system programming group has continued developing the Compatible Time-Sharing System (CTSS) for the IBM 7094 computer of Project MAC. This evolution has allowed the constant modification and testing of new ideas in a framework of man-machine interaction. In fact, the ability of the system to evolve with time has been a basic design goal. Hardware requirements in the past year have also caused further programming requirements. Two IBM 7320A high-speed drums, attached to the MAC computer in August, have significantly improved response times.

Thus, time-sharing at Project MAC has been: 1) a service facility which has allowed individual users to explore the consequences of man-machine interaction, and 2) a laboratory in which system programmers can develop the tools needed for effective man-machine interaction. The 7094 system is still in the process of being tuned, though it is incapable of being tuned to any high degree because the basic multi-programming ability and storage allocation techniques are very difficult. For this reason, a second-generation time-sharing system called MULTICS (for Multiplexed Information and Computing Service) will be implemented initially on a GE 645 as a development project with the Bell Telephone Laboratories and the General Electric Computer Department.

The Multics Project was started this year, and papers describing the system are to be presented at the Fall Joint Computer Conference, 1965. The major design decisions which have been made are in the area of hardware. A separate report by E. L. Glaser covers hardware design. Software plans have been harder to firmly establish.

Tuning and improvement of the 7094 system has been done with two motives; there has been the desire to develop an accurate pilot model of possible future systems, and there has been great interest to learn from mistakes. On both counts it is felt that considerable success has been achieved during the past year. A detailed description of the 7094 system may be found in the Compatible Time-Sharing System, 2nd edition, M.I.T. Press, 1965. What follows is a brief review of the major elements of the evolvement of the 7094 system.

It has been recognized that the disk file system is a major and central part of a time-sharing system. Already CTSS has one of the most elaborate file systems developed. Nevertheless, it is also recognized that the first version of the file system is inadequate for a more highly-tuned time-sharing system. Some of the changes that have been improvements are the salvager and an improved input/output editor for placing or removing material from the disk file. These changes have improved the reliability and smoothness of system operation inasmuch as the features involved occupy pivotal software roles and are expected to always function without mishap.

However, of major importance has been the design of the second-generation file system. This major redesign is expected to correct four areas of difficulty. One, it should be possible to share files among many users, thereby allowing multiple reading and suitable interlocking upon writing. Two, multiprogramming should be possible such that more than one user can be using the file system simultaneously. Three, it should be possible to use magnetic tapes from within the time-sharing system. Four, it should be possible to incrementally dump only newly-created material, on a continuous basis, rather than have a massive dump periodically (e. g., once a day) of the entire contents of the disk. This process is being developed under the program name DAEMON. Basic design was concluded in the fall of 1964. Implementation was begun and is now approaching the terminal stages. The implementation of this new file system is considered of prime importance, as it gives the programming staff an opportunity to shake-down the multitude of ideas which are involved in anticipation of MULTICS.

Other improvements to CTSS have been the introduction of a class of new editing programs for typing in programs, text, etc. Of notable interest has been the development of the TYPSET and RUNOFF commands for English text and the corresponding ED and EDL commands for program text. These programs are based on a synthesis of many editing techniques by J. Saltzer and have mostly replaced the need for the previous editors such as MEMO, MODIFY, DITTO, INPUT, EDIT, and FILE. The new

editors are distinguished by a high degree of sophistication for man-machine interaction as well as context editing techniques which avoid fixed format requirements.

In addition, nearly all commands of the system have had some corrections or improvements. Particularly notable are: inclusion of a new version of the MAD compiler; cleaning up and fixing up of the FAP command to allow use of more compacted input files; improvement of the LOAD command to allow three different program libraries and thus speed up library searching; and reprogramming of FILE, RUNCOM, SPLIT, COMBIN, SNOBAL and other commands. Further new features have been added in the form of interconsole message facilities and the ability to "attach" other consoles. In addition, new debugging techniques have been introduced, the most notable being the MADBUG program of R. Fabry for the FAPDBG-like debugging of MADBUG programs. The MADBUG program is considered only a prototype of future debugging techniques, as the present CTSS implementation forces it to be relatively clumsy. Nevertheless, the design goal, that the MAD language user need not know machine language, has largely been met.

Finally, there have been numerous attempts to find solutions for the difficult problem area of system documentation. There have been many attempts to compact disc space requirements and allow larger utilization of the available secondary storage capacity. In particular, the ARCHIVE and CRUNCH commands have been developed. In addition, the LOG command has been developed to notify system users and allow user teams to keep posted all system changes of current interest. Moreover, the system programmers themselves have developed conventions and procedures in an attempt to systematize record keeping for a large system. In addition, facilities have been developed for semi-automatic "carry" of programs back and forth between the two 7094 computers to allow smoother and easier maintenance of two slightly different CTSS systems.

Of major importance in the orderly development of the new system has been a complete revision of the present CTSS Programmer's Guide to include information from many CTSS Bulletins and important MAC memos describing changes in the features of the system. This revised manual will be maintained on-line in the computer and is available to any user at any hour of the day or night whether he be 20 feet or 2000 miles away from the Computer. In this way, users may keep abreast of the latest system changes. In particular, a user is given the ability to read a table of contents of the changes listed in reverse chronological order. It is expected that the manual, which can be maintained by the system programming staff in as dynamic a state as the system itself, will be a significant part of the answer to documentation difficulties of future remote-console systems.

MULTICS Hardware System Design - Edward L. Glaser

During the reporting period, the hardware design for the new Multiplexed Information and Computing Service (MULTICS) time-sharing system was formulated and frozen. This design consists of rather extensive modifications to a General Electric 635 computer. The resulting computing system is to be known as the General Electric 645 computer. Extensive modifications were carried into a number of different areas. First of all, the addressing logic was enhanced to incorporate the concepts of segmentation and paging.* Additionally, some new instructions were added to the instruction repertoire, and the interrupt logic was enhanced, making it possible to interrupt an instruction part way through execution, and subsequently continue with the execution of this instruction. These explicit modifications will enable the system to handle software envisioned for the new time-sharing system.

The second major area of design was that of a general I/O control unit. This I/O control unit incorporated functions of both a standard I/O control channel and a communications computer. Thus, the same equivalent logic could be used to communicate with both standard computer peripherals, such as magnetic tape, disc, and card equipment, and with varying communication lines from teletype speed to very high speed for displays.

The generality of design is intended to make modular software in the new time-sharing system not only feasible but efficient. Further, specific features are incorporated into the design of the I/O equipment control unit to facilitate processing of many interrupts in a short period of time, which is necessary on any system connected to a large number of remote terminals.

The third major area of design is that of a new high-speed drum controller to be used in conjunction with a large-capacity drum. The availability of this new drum controller with its associated drum will facilitate time-sharing for two reasons: first, the transfer rate between the drum and core memory is approximately fifty percent of memory speed; second, because of the way the drum controller operates, it is possible on a statistical basis to ignore any latency due to the rotary access to the drum.

Details on all of these design areas will be available in papers to be presented at the Fall Joint Computer Conference, 1965.

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* See (1) Dennis, J. B., "Program Structure in a Multi-Access Computer," Project MAC Technical Report MAC-TR-11; and (2) Dennis, J. B. and Glaser, E. L., "The Structure of On-Line Information Processing Systems," Information System Sciences, Proceedings of the Second Congress, Spartan Books, Inc.

APPENDIX A

PROJECT MAC MEMORANDA

MEMORANDUM MAC-M/No.	SUBJECT	AUTHOR	DATE
172	On-Line Documentation of the Compatible Time-Sharing System	J. Winett	7/21/64
173	SQZ/PADBIN (Ref: MAC-M-157)	R. Hussey	7/20/64
174	Abstracts of CTSS Console Commands (CC239) (174-2, 1/4/65; 174-3, 3/7/65	E. Kliman	8/3/64
175	Access to the MAC System via Alternate-Use-TWX ("TWX≠Prime")	R. G. Mills	7/24/64
176	String Manipulation in the New Language (AIP memo 71)	D. Bobrow	7/28/64
177	CTSS Library Abstracts (CC240) (177-2, 11/23/64; 177-3, 3/22/65	E. Kliman	8/6/64
178	Crunch Command in CTSS	R. Bayles	8/7/64
179	BEFAP Command within CTSS	R. Bayles	8/10/64
180	The ARCHIV Command	A. Scherr	10/19/64
181	The Structure of On-Line Information Processing Systems	E. Glaser J. Dennis	10/1/64
182	Preliminary Notes on the Hard Matter for the MAC 635	E. Glaser	8/28/64
183	Proposed Instructions on the GE 635 for List Processing and Push Down Stacks (AIP memo 72)	M. Levin	9/18/64
184	On Memory Addressing in the GE 635	M. Minsky M. Levin	9/22/64
185	MAC and Its Users	U. Neisser	9/29/64
186	A Note on Asynchronous Parallel Processing (MSG memo 5)	H. Witsenhausen	7/64
187	Nesting and Recursion of Procedure in Segmented Memory (MSG memo 6)	J. Dennis E. C. Van Horn	10/28/64
188	Automatic Scheduling of Priority Processes	J. Dennis	10/64

MEMORANDUM MAC-M-No.	SUBJECT	AUTHOR	DATE
189	An Example of Intersphere Communication and Asynchronous Parallel Processing: Typewriter Console Message Handling by Protected Service Routines (MSG memo 8)	J. Dennis	9/25/64
190	General Comments about PDP-6 Coding and Hardware (PDP-6 memo 1)	D. Edwards	9/25/64
191	TECO 6 (PDP-6 memo 2)	D. Edwards	
192	Unrecognizable Sets of Numbers (AIP memo 73)	M. Minsky S. Papert	11/2/64
193-2	TYPSET and RUNOFF, Memorandum Editor and Type-out Commands (CC 244-2)	J. Saltzer	11/6/64
194	On the Control Specifications of Computation	D. Kuck	11/64
195	ED, A Context Editor for Card Image Files (195-1, 3/15/65) (CC245; CC234-1)	R. Dailey	11/20/64
196	Some Aspects of the Structure of Computation	D. Kuck R. Kain	11/13/64
197	Some Time-Sharing Ideas	D. Kuck	11/13/64
198	PLEX-Dump and Relocation in the AED-O System (9442-M-110)	T. Fox	10/26/64
199	Stack Manipulation Facilities of the AED-O Language (9442-M-112)	R. Coe	11/18/64
200	Processes, Spheres of Protection and Independent Computation (MSG 9)	E. Van Horn	(no date)
201	New Operating System for the ESL Display Console (9443-M-118 (Cont'd 12/10/64)	R. Bayles	11/23/64
202	Proposal to Improve the Rotation Matrix of the ESL Display Console (9442-M-114)	R. Stotz	11/27/64
203	A Compacting Free Storage Program (9442-M-113	B. Wolman	3/5/65
204	AED-O Compiler for Batch Processing (9442-M-115	H. Spencer	12/2/64

MEMORANDUM MAC-M-No.	SUBJECT	AUTHOR	DATE
205	MADBUG: A MAD Debugging System (CC247)	R. Fabry	11/25/64
206	CTSS LISP Notice: Supplement to A. I. Memo No. 67 (AIP memo 74)	T. Hart	12/7/64
207	Internal Memos for AED Users (9442-M-116)	C. Feldmann	12/8/64
208	AED Flash 10, New CTEST2 Command (9442-M-119)	C. Feldmann	12/10/64
209	The Naval Mine Warfare Game	I. Sutherland	12/18/64
210	Graphical Output Device	A. Rutchka	12/21/64
211	New TWX-Prime Lines	R. G. Mills	12/23/64
212*	Translation of Communication with Automata by Carl Adam Petri	O. Selfridge	6/10/65
213	AED FLASH 11: AED BUG Usage (9442-M-121)	T. Fox	12/28/64
215	Television Camera-to-Computer Adapter: PDP-6 Device 770 (AIP memo 75)	M. Minsky	1/9/65
216	New B-Core System for Programming the ESL Display Console (9442-M-122)	C. Lang	4/30/65
217	Operating Manual for the ESL Display Console (9442-M-129)	R. Stotz J. Ward	3/9/65
218	Social Science Data Bank Development	I. D. Poole	1/21/65
219	The COMIT Feature in LISP II (AIP memo 76) (LISP II Project Memo 2)	D. Bobrow	2/18/65
220	The COGO Language	D. Roos	2/25/65
221	The INFO Command	J. Winett	2/25/65
222	AED FLASH 12: Multi-Entry Procedures (9442-M-124)	D. Ross	2/25/65
224	An Automatic Plotting Subroutine, XYPLOT	T. Stockham, Jr.	3/3/65

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* In older listings of MAC-M-memos, this memo was numbered as MAC-M-214.

MEMORANDUM MAC-M-No.	SUBJECT	AUTHOR	DATE
225	AED FLASH 13: Argument Checking Procedures for AED (9442-M-125) (225-2, 4/15/65)	J. Walsh	3/5/65
226	AED FLASH 14: Availability of AED JR Systems (9442-M-126)	D. Ross	3/9/65
227	The Editing Routine	D. Griffel	3/8/65
228	A General Cross-Tabulation System (COM/COM Sim. memo 23) (See Additional Information on Cross-Tabs: New Output)	W. Selles	4/24/65
229	Proposed Datanet-30 Program	S. Dunten	3/18/65
230	Mind, Matter and Models (AIP memo 77)	M. Minsky	3/26/65
231	Description of SNOBOL Commands (CC235-2)	L. Pouzin	4/9/65
232	Preliminary Description of DAEMON, the Disk Dump and Reload Program Package, and its Operation (CC 252)	M. Bailey	4/26/65
233	Trial Launching of the OPS-3 System	M. Jones D. Ness	4/26/65
234	Users' Manual on the Use of Structural Language	R. Logcher	9/15/65
235	BLODI Command	O. Wright, Jr.	5/4/65
236	AED FLASH 15: Execution Time Procedure Calls (9442-M-131)	J. Walsh	4/22/65
237	A Generalized File Structure and Input/Output System (CC 241-1)	R. C. Daley R. J. Creasy R. M. Graham	5/7/65
238	Some Facilities of the MAC Document Room	Document Room (A. Bowen)	5/10/65
239	KREADQ, SETRDQ, MODRDQ, A Set of Format-Free Input Subroutines	D. Ness	6/16/65
240	Topics in Model Theory	M. Levin	5/25/65
241	PDP-6 LISP Input-Output for the Dataphone (AIP memo 79)	W. Martin	6/1/65

MEMORANDUM MAC-M-No.	SUBJECT	AUTHOR	DATE
242	PDP-6 LISP Input-Output for the Display (AIP memo 80)	W. Martin	6/28/65
243	Specifications for a Dataphone-Driven Remote Display Console for Project MAC	R. H. Stotz J. E. Ward U. F. Gronemann	6/24/65
244	Proposal for Commands for Dynamic Resource Allocation (CC 254)	G. Schroeder	4/17/65
245	DIRECT; A Command Subroutine for Controlling Programs	T. Crystal E. River	6/23/65
246	Computer Experiments in Finite Algebra	W. D. Maurer	6/14/65
247	AED FLASH 16: Use of AED JR to Parse FORTRAN II (9442-M-134)	H. Spencer	6/25/65
248	Use of MACDMP (AIP memo 83)	P. Samson	7/1/65
249	MAC PDP-6 DECtape File Structure (AIP memo 82)	P. Samson	7/1/65
250	PDP-6 TECO, July 1965 Version	P. Samson	7/23/65
251	AED FLASH 17: Features of the Revised AED-JR (9442-M-136)	J. F. Walsh R. Feldmann	7/1/65
252	AED FLASH 18: A Subroutine for Generating Coons' Surfaces (9442-M-137)	C. Lang	6/30/65
253	FMS Tape Distribution (9442-M-127-3)	R. Feldmann D. E. Walker	7/1/65
254	Derivation of a Mean Pseudo-Associative Search Time (MSG memo 13)	E. C. Van Horn	8/16/65
255	Surfaces for Computer-Aided Design of Space Figures (9442-M-139)	S. A. Coons	7/21/65
256	Three-Dimension Pseudo Pen Sub-routine for use with the ESL Display Console (9442-M-138)	R. Polansky	7/13/65
257	Syntax and Display of Mathematical Expressions (AIP memo 85)	W. Martin	7/29/65

MEMORANDUM MAC-M-No.	SUBJECT	AUTHOR	DATE
	. . . REVISIONS . . .		
168-2	A Subroutine Trace Program for CTSS	B. Wolman	3/5/65
174-3	CTSS Console Commands	E. Kliman	3/7/65
177-3	CTSS Library Subroutines	E. Kliman	3/22/65
193-2	TYPSET and RUNOFF, Memorandum Editor and Type-out Commands (CC-244-2)	J. Saltzer	1/11/65
195-1	ED, a Context Editor for FAP and MADTRN Program	R. Dailey	3/15/65

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13. ABSTRACT

The broad goal of Project MAC is experimental investigation of new ways in which on-line use of computers can aid people in their individual work; whether research, engineering design, management, or education.

This is the second annual Progress Report summarizing the research carried out under the sponsorship of Project MAC. The details of this research may be found in the publications listed at the end of the report.

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